

**Domestic Preparedness Program: Phase 2 Sarin (GB) and
Distilled Sulfur Mustard (HD) Vapor Challenge Testing of
Commercial Self-Contained Breathing Apparatus
Facepieces**

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PREFACE

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Table of Contents

1. EXECUTIVE SUMMARY	7
2. INTRODUCTION	7
3. OBJECTIVES AND SCBA DESCRIPTIONS.....	8
4. CHEMICAL AGENT TESTING	9
A. Chemical Agent Testing Equipment.....	9
(1) Vapor Generator.....	9
(2) SCBA Facepiece Exposure Chamber	9
(3) Breather Pump	10
(4) MINICAMS	10
B. Chemical Agent Testing	10
C. Chemical Agent Test Results and Discussion	11
5. CONCLUSIONS.....	13
Appendix A - Glossary	14

Tables

Table 1. Conditions Used for Testing SCBA Facepieces.....	11
Table 2. Detection of Agent Inside Facepiece	12

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Domestic Preparedness Program: Phase 2 Sarin (GB) and Distilled Sulfur Mustard (HD) Vapor Challenge Testing of Commercial Self-Contained Breathing Apparatus Facepieces

1. EXECUTIVE SUMMARY

This report presents the results of testing three different self-contained breathing apparatus (SCBA) against vapors of GB (Sarin), a nerve agent, and HD (distilled sulfur mustard), a vesicant agent. The challenge concentration of both agents was 200 mg/m³ which is a higher concentration than these respirators would be used in, but which, in the laboratory, gives a rigorous evaluation of the item.

The air cylinders that are supplied with the respirators were not used during the agent tests; instead, high pressure air from the laboratory was used to supply breathing air to the facepieces. This allowed the tests to be run for 60 minutes for each item, even though the nominal times of use for the three SCBAs were 15 and 30 minutes (one SCBA has an optional 60-minute cylinder).

The 3M SCBAG resisted both HD and GB for 60 minutes (average of three tests). Two of the Interspiro Spiroscape facepieces resisted HD for 60 minutes (average of three tests). One facepiece was later found to be defective, and it broke through in 12 minutes. One of the Interspiro Spiroscape facepieces resisted GB for 30 minutes, but the other two had agent inside within 4 minutes. The North Model 821 resisted HD for 60 minutes (average of three tests) and GB for 25, 28, and 32 minutes.

A glossary of terms used in this report is included as Appendix A.

2. INTRODUCTION

In 1996, Congress passed Public Law 104-201 (Defense Against Weapons of Mass Destruction Act of 1996), directing the Department of Defense (DoD) to assist other federal, state, and local agencies in enhancing preparedness for terrorist attacks using weapons of mass destruction. The DoD responded, forming the Domestic Preparedness Program that same year. One of the objectives of the Domestic Preparedness Program is to enhance federal, state, and local emergency and hazardous material (HAZMAT) response to nuclear, biological, and chemical (NBC) terrorism incidents. As part of an effective response, emergency and HAZMAT personnel who are responding to an incident will use personal protective equipment (PPE) to protect themselves from exposure to chemical or biological agents. The specific PPE that will be

used by these personnel would depend on the situation encountered and what PPE is held in inventory. In some cases, commercial self-contained breathing apparatus may be used to enter a contaminated or potentially contaminated area. This program tasked the Edgewood Chemical Biological Center (ECBC) of Research, Development and Engineering Command (RDECOM) to perform chemical agent vapor testing of some commercial SCBA. A SCBA is an atmosphere-supplying respirator for which breathing air is designed to be carried by the user, that is, the breathing air is contained in a compressed gas cylinder that the user carries with him.

3. OBJECTIVES AND SCBA DESCRIPTIONS

The objective of this project was to determine whether there was any inward leakage or permeation of agent through the facepieces of three commercial SCBAs under a very high challenge concentration of GB and HD vapor, while the facepieces were mounted on a manikin in a closed exposure chamber and operated by a breather pump. The reason for using the high challenge concentration (200 mg/m^3) is that leaks or permeation are more readily detected under these conditions, and the integrity of the respirator more easily evaluated. These SCBAs were operated in the pressure demand mode. Air cylinders, valves, harnesses, and other parts of the SCBAs were not tested. High pressure air from a laboratory source was supplied to the facepieces. Samples of air from inside the facepieces were taken from both the eye and nose areas and analyzed by MINICAMS.

The 3M™ SCBAG™ (BA-4430M) system, from 3M™ Occupational Health and Environmental Safety Division, St. Paul, MN, comes in a carrying bag that opens to form a vest with the SCBA system already in place. The system includes a full facepiece with speaking diaphragm, and a soft, double-flange seal. It also features a 30-minute, 4500-psi cylinder of air. It has an optional airline connection that allows the wearer to remain in the area for longer periods of time. This system is NIOSH certified.

The North 821 system (facepiece 80004, demand valve 80014), from North Safety Products, Cranston, RI, has a 30- or 60-minute air cylinder that is worn in a harness on the back. It has a full facepiece constructed of soft silicone, a dual sealing flange, and a speaking diaphragm. An oronasal cup reduces fogging on the polycarbonate lens. The demand valve can provide over 300 liters of air per minute at peak inhalation. This system is NIOSH certified.

The Interspiro Spiroscape, from Interspiro, Inc., Branford, CT, is not strictly an SCBA, but is here regarded as such since it includes a 10- or 15-minute cylinder of air. It is

actually an emergency escape breathing apparatus. The hood has a latex rubber neck seal. The inner mask has an exhalation valve that minimizes fogging and carbon dioxide build-up, and eliminates need for a demand valve. This item is NIOSH certified as a compressed air emergency escape breathing apparatus.

None of the three SCBAs was intended for use in an IDLH (immediately dangerous to life or health) agent environment.

4. CHEMICAL AGENT TESTING

A. Chemical Agent Testing Equipment

(1) Vapor Generator

GB and HD vapors were generated by using a syringe pump that injected liquid agent into a heated tee in the air dilution line. The rate of injection was such that the concentration of agent was controlled to that specified in the test plan. The agent was vaporized in the heated tee and carried by the dilution air into the mixing chamber. The mixture was then injected into the exposure chamber. An infrared Ambient Air Analyzer (MIRAN), Model 1A, was used to monitor the agent concentration in the exposure chamber during the test. The MIRAN was standardized by injecting known volumes of CASARM (Chemical Agent Standard Analytical Reference Material) grade agent into air in the closed sampling cell, which is recirculated by an external pump. Monitoring was performed through a probe located in front of the facepiece.

(2) SCBA Facepiece Exposure Chamber

The exposure chamber was a Plexiglas® box approximately 2 feet on each side, with a removable front panel and four legs on the bottom about 4 inches long, which allowed air to flow under the chamber when it was located inside a fume hood. The test fixture is SMARTMAN, (SiMulant Agent Resistant Test MANikin; see glossary), which is a human head form, medium size, with a movable face section and an inflatable peripheral seal that ensures the facepiece section of the mask is securely sealed. The mouth orifice of the fixture is connected to a breather pump. There are two sampling tubes in the nose, one in the eye, and one in the forehead. These tubes pass down through the interior of the fixture through the floor of the chamber, and connect to remote detectors. Since agent-air mixtures pass through the exposure chamber during the test, the outlet ports on top of the chamber are covered by military M12A1

filters to scrub agent from the passing air. Other ports in the chamber walls are used for introducing the agent challenge into the chamber, to attach pressure gauges, to introduce liquid aerosol for preliminary leak testing, or to monitor the agent concentration inside the chamber. The challenge airflow rate is double that of the minute flow of the breather pump to assure that challenge concentration is not diluted by clean air.

(3) Breather Pump

The military Breather Pump E1R1 (Jaeco Fluid Systems, Inc., Exton, PA) was used to simulate breathing through the SCBA facepieces. This is a reciprocating pump that produces a harmonic (sinusoidal) breathing pattern by means of a reduction planetary gear system that incorporates a Scotch Yoke. The peak flow produced by this pump is approximately π times the minute volume; in the tests performed, the peak flow was approximately 78 liters per minute. The minute volume (liters pumped in one minute) and the number of strokes per minute (breaths) can be adjusted on this pump.

(4) MINICAMS

The MINICAMS (Miniature Continuous Air Monitoring System) is a gas chromatograph equipped with a flame photometric detector and a preconcentrator tube. The preconcentrator tube is a small diameter tube containing an adsorbent material to collect agent vapor contained in a sample of air drawn through it for a set period of time. The tube is then heated to desorb the agent and introduce it into the column and subsequently the detector. By preconcentrating the agent, the detection limit is lowered. The MINICAMS software calculates the amount of agent detected over the sampling period. The MINICAMS is standardized by injecting known amounts of agent onto the column.

B. Chemical Agent Testing

The SCBA facepiece was mounted on the SMARTMAN by tightening the straps of the harness. The peripheral seal was inflated (3-5 psi) to form a tight seal against the inside of the facepiece. This seal is artificially good and may not be representative of the seal obtained by a user of the facepiece. It is therefore important that users follow manufacturers' instructions for developing a good seal of the facepiece against the face. Before an agent test was started, a liquid aerosol leak test was performed, using the TDA-99M Aerosol Leak Detector (See glossary). The detector section of the tester was connected to one of the SMARTMAN sampling

ports inside the respirator, and the aerosol was directed through a hollow wand against the facepiece and the seal. This is a preliminary check that can isolate leaks. The breather pump was turned on during this test. If no leak was detected, then the chamber was closed and the aerosol was injected into the exposure chamber to challenge the entire system. If a leak was detected, the leak path was found and corrected. If no leak was detected, then the agent test was performed.

For the agent test, the MINICAMS detector was connected to two ports (the eye and nose areas) to monitor for presence of agent inside the facepiece. The agent challenge, generated as described above, was passed from the mixing chamber into the SCBA exposure chamber. Each type of facepiece was tested three times with HD and three times with GB. Table 1 lists the conditions used for testing.

Table 1. Conditions Used for Testing SCBA Facepieces

Rate of air flow through exposure chamber	50 L/min
Concentration of agent challenge	200 mg/m ³
Total test time if breakthrough is not observed	60 minutes
Temperature of test chamber	25±3°C
Flow rate of breather pump	25 L/min
Pump strokes per minute	25
Volume per breath	1 Liter

C. Chemical Agent Test Results and Discussion

The test results on the three types of SCBA are presented in Table 2. If no agent was detected inside the facepiece, the result is noted as “BDL” (below detection limit). If agent was detected inside the facepiece, the time from the beginning of the test to a concentration of 0.007 mg/m³ for GB and 0.003 mg/m³ for HD, is given in minutes.

Table 2. Detection of Agent Inside Facepiece

Respirator	Test Duration (minutes)	Agent	Results 1 Hr mg/m³	BP, (minutes)
3M SCBAG (BA-4430M)	60	HD	BDL	NA
			BDL	NA
			BDL	NA
	60	GB	BDL	NA
			BDL	NA
			BDL	NA
Interspiro Spiroscape	60	HD	Detected	12
			BDL	NA
			BDL	NA
	60	GB	Detected	30
			Detected	<4
			Detected	<4
North Model 821	60	HD	BDL	NA
			BDL	NA
			BDL	NA
	60	GB	Detected	28
			Detected	25
			Detected	32

BDL Below Detection Limit

BP Break Point

NA Not Applicable

The 3M SCBAG resisted permeation/penetration of both GB and HD for the 60-minute test time. Two of the Interspiro Spiroscape respirators tested with HD showed no agent inside the facepiece after 60 minutes. The third SCBA had a small hole in the facepiece found with the TDA-99M Leak Tester. Since a replacement was not available, the hole was covered with a piece of tape before the HD test. However, agent was detected inside after 12 minutes. This cannot be regarded as a valid test. The Spiroscape tested against GB had agent inside the facepiece after 30 minutes in one case; the other two had agent inside in less than 4 minutes. North Model 821 SCBA resisted HD for 60 minutes in all three tests; however, GB was detected inside the other three facepieces after 25, 28, and 32 minutes.

The aerosol leak test is performed to assure a tight seal between the facepiece and the test fixture, and that there are no leak paths, such as pinholes. The fact that there is no aerosol detected inside the facepiece does not indicate that there will not be vapor detected inside, since aerosol size is rather gross compared with molecular vapor, and vapor can possibly

penetrate seals, exhalation valves, or holes much too small to permit aerosols to penetrate. It is also possible for vapor to permeate susceptible areas of the polymer of the facepiece.

5. CONCLUSIONS

One SCBA, the 3M SCBAG (BA-4430M) resisted both HD and GB vapor for one hour, and might be considered useful in agent vapor environments. The other two, Interspiro Spiroscape and North Model 821, gave inconsistent results, resisting HD for one hour but not GB. Without further testing, it is unknown whether these two should be considered for use in agent vapor environments.

APPENDIX A

GLOSSARY

Ambient Air Analyzer (MIRAN) Model 1A

Manufactured by Thermo Environmental Instruments Inc. It is an infrared absorption based detector that uses a long path length cell up to 20 meters, into which the air sample is introduced. This analyzer is used to monitor the challenge concentration of vapor in the test chamber.

Facepiece

The portion of a respirator that covers the wearer's nose and mouth (a full facepiece also covers the eyes). The facepiece should make a gas-tight or dust-tight seal with the face. The facepiece is supported by headbands, and contains exhalation valves and connectors for breathing air.

Leak Detector TDA-99M

The TDA-99M is manufactured by Air Techniques, Inc, Baltimore, MD, and is one of the primary tools for assessing aerosol leaks in the mechanical seals of the respirator and the correct fitting of a respirator facepiece to the SMARTMAN test fixture. The device generates a liquid oil aerosol (Emory 3004) that is used to detect leakage into the interior of the respirator.

MINICAMS®

Trade name for a chemical agent detector in which the agent is adsorbed from a specified volume of air onto an adsorbent tube which is then desorbed into the injection port of a gas chromatograph for analysis (quantitation). The acronym stands for "Miniature Continuous Air Monitoring System."

Sarin

An organophosphorus nerve agent, known by the military symbol GB. The chemical name is isopropyl methylphosphonofluoridate. GB reacts with the enzyme cholinesterase, thus interfering with the transmission of nerve impulses.

Self-Contained Breathing Apparatus

An Open-Circuit Self-Contained Breathing Apparatus is designed to provide the wearer with an atmosphere independent of the ambient air. The air is supplied by a cylinder that is carried on the back of the wearer or by a hose from a compressor.

SMARTMAN

Manufactured by ILC Dover, Frederica, DE. The **Simulant Agent Resistant Test Manikin**, SMARTMAN, is a cast zinc, hollow shell and comprised of a head, neck, shoulders, and upper chest. The head features an anatomically correct surface consisting of dimensional eyes, nose, ears, mouth, forehead, and chin. The facial features are on a movable section of the head to facilitate installing and removing a peripheral front face seal, which is made of rubber and fits into a channel between the face and the permanent part of the head. The seal is inflated to press against the inside of the facepiece seal area to assure against leakage.

Syringe Pump

A multirange, variable rate infusion pump is used to inject liquid agent at a controlled rate into an air stream to generate a vapor challenge. The liquid agent is contained in a syringe connected by a flexible cannula. The plunger of the syringe is driven at a controlled rate by the pump to deliver a constant flow of agent. The concentration of agent is adjusted by changing the speed setting of the pump.